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VOL. XII. 4 SEPTEMBER, 1918. No. 7

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PLATE IX.

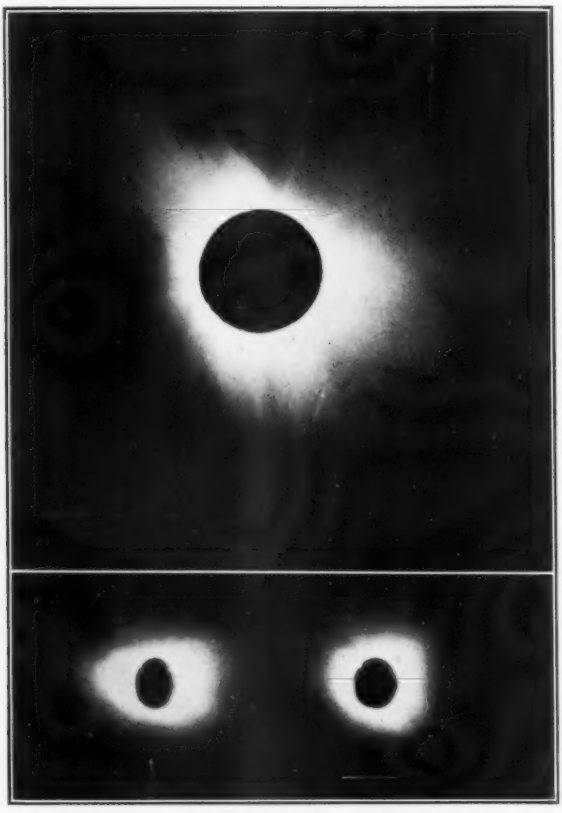
ECLIPSE STATION, MATHESON, COLORADO

Pettit Chant Morehouse Loud

Chant, Morehouse, Pettit, F. H. Loud, Hartley,
Whisler, Neal, Owens. Smith, F. M. Loud,
Mrs. Whisler. Miss Gushee, Miss Steele.

OBSERVERS AT ECLIPSE STATION, MATHESON, COLO.

PLATE X.



THE CORONA, JUNE 8, 1918

Above: with a 4½-inch telescope, exposure 5 sec.
Below: with polariscopic camera. The straight lines show the planes of polarization.

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VOL. XII. SEPTEMBER, 1918. No. 7

THE SOLAR ECLIPSE OF JUNE 8, 1918; OBSERVATIONS AT MATHESON, COLORADO

BY C. A. CHANT

THE path of totality of this eclipse began at sunrise near the island of Borodino, south of Japan, passed east and north across the Pacific Ocean until it neared Alaska, and then, turning somewhat to the south, entered the United States near the mouth of the Columbia River. It crossed the states of Washington, Oregon, Idaho, Wyoming, Colorado, Kansas, Oklahoma Arkansas, Missouri, Alabama and Florida; and, continuing into the Atlantic Ocean, it left the earth at sunset near the Bahama Islands. At the middle of its course, south of Alaska, at local noon, the duration of the total phase was $2^m\ 23^s$, and on reaching the coast, at 3.55 "summer" Pacific Time, it was $2^m\ 1^s$ and the altitude of the sun was 50°. Going farther east, the duration of totality diminished and the altitude decreased, until, on leaving Florida, at 7.42, "summer" Eastern Time, the duration was about 50^s and the altitude about 10°. The entire time required by the shadow to traverse its diagonal path from ocean to ocean was 47 minutes.

For obvious reasons, sites in the far west were chosen for astronomical observations, but afternoon skies in the west in

early June are very uncertain. A party under Director Campbell, of the Lick Observatory, was located near Goldendale, Wash., and after hope of success had almost been abandoned on account of thick clouds, at about a minute before the beginning of the total phase the clouds separated, and so they remained until the entire program had been successfully carried out, when they came together again. At Baker City, Ore., where the U.S. Naval Observatory had a party, observations were made through thin clouds. Farther east, at Green River, Wyo., extensive preparations had been made by the Yerkes and Mt. Wilson Observatories, but one slight cloud somewhat marred the obser vations. At Rock Springs, Wyo, where Professor Joel Stebbins was stationed, the sky was clear. At Fraser, Colo., were Professor F. P. Leavenworth and Mr. W. O. Beal, of the University of Minnesota Observatory ; Professor H. C. Wilson, of Goodsell Observatory, and Mr. J. H. Darling, of Duluth, Minn. The sky was clear at the time of totality. At Denver the sun was completely obscured by clouds, to the great disappointment of a large number of representatives from the Chamberlin, Yerkes and Allegheny Observatories and other places. Sixty miles farther on is Matheson, of which more will be said in what follows. At Brandon, Colo., the joint expedition from the Sproul Observatory, Swarthmore, Pa., and the Kirkwood Observatory, University of Indiana, had a clear sky. Near Syracuse, Kan., the Lowell Observatory expedition had thin clouds. The Smithsonian Astrophysical Observatory had a station between Hartland and Lakin, Kan., and had a clear sky. Dr. Louis Bell, of Boston, was at McAlester, Okla., and reports a moderately clear sky. At Cocoa, Fla., where Professor and Mrs. D. P. Todd were, the sun was obscured by clouds.

Early in the year Professors Frost and Barnard, of the Yerkes Observatory, and Loud, of Colorado Springs, made a tour by motor, searching for suitable sites in Colorado, and one suggested by them was near Matheson, a small village on the Rock Island Railway. In this part of the country at this time of the year the sky, while usually clear in the morning, has

many clouds in the afternoon, especially in the west; but being farther from the mountains than Denver, it was thought that prospects would be better for a clear sky than at that city. The country is rolling, and the summit of a hill, which looked only half a mile away, but which proved to be about two miles, west of the village, was chosen as a site for observations and was known as the Colorado College Eclipse Station. Professor Frank H. Loud, lately retired from Colorado College, made preliminary arrangements for the observers.

The geographical coördinates of the site are:

Longitude $6^h\ 55^m\ 56^s$ W.

Latitude $39^\circ\ 10'$

Height above sea level, about 6000 feet.

There were four separate installations. The most extensive was that from the Washburn College Observatory, Topeka, Kan., in charge of Professor Edison Pettit, of that institution. He was assisted by Miss Hannah B. Steele, of Yerkes Observatory; Miss Vera M. Gushee, of Smith College Observatory; and Messrs. Finley F. Neal and Roy Owens, of Kansas. The Yerkes Observatory, where Professor Pettit had been acting as assistant for a half year, was also interested in this outfit. In the upper end of a square tube, directed towards that point in the sky to be occupied by the sun at the time of totality, was a lens 12 inches in diameter and of focal length 14 feet. As the lens was to be used for photography, its aperture was stopped down to 4 inches. The lower end of the tube projected into a light-tight house, and the image of the sun was received upon a 10×12 plate moved by clockwork. Attempts were made to obtain some record of the sun's surroundings before and after totality by shielding the plate from the direct sun by placing on the plate a circular object of precisely the same size as the sun's image. Three exposures were made just before and one just after totality. In addition, during totality six exposures, of various lengths, were made and some good negatives were secured.

Besides this, the 'flash' spectrum was photographed with a

single prism with a camera of aperture 1¼ inches and focal length 24 inches. Four exposures were also made during the total phase with a telescope of focal length 54 inches and aperture 1½ inches.

Readings of an aneroid barometer were made, by the aid of a magnifier, before, during and after totality. The change, if any, during the eclipse was very small—possibly a minute rise.

A recording thermometer was also included in the equipment; during totality the temperature fell about 3½° F.

Mr. Pettit's party also had a chronometer, which was checked by time signals received at the railway station, and which supplied time for all the observations made at the station.

Another installation was from the Drake University, Des Moines, Ia. Professor D. W. Morehouse, of that institution, had transported his 8¼-inch Brashear refractor, together with a 5-inch photographic doublet, mounted on the tube. With the assistance of Mr. Donald M. Smith, a recent graduate of Drake University, exposures of varying lengths were made simultaneously with these two instruments. The telescope was furnished with two flint-glass components of the object glass, and the instrument was adapted for visual or for photographic use by using one or the other of these. Some excellent negatives were obtained.

The outfit from Colorado College, which is located at Colorado Springs, consisted of three cameras on a single mounting. The objectives of these were as follows:

Cooke anastigmat,	f = 11 inches, aperture f/11
Cooke anastigmat,	f = 8 inches, aperture f/4·8
Goerz single anastigmat,	f = 18 inches, aperture f/16.

The motion in right ascension was produced in a very simple and ingenious manner. Carefully sifted sand, placed in a sheet-metal tank, was allowed to run out through a small hole in the bottom; and as it ran out, a heavy weight placed on the top of it descended slowly and uniformly. To this weight was attached a wire cable, which, after passing over several pulleys, was

wound about the axis to be rotated. The apparatus worked admirably. Mr. Kenneth Hartley assisted Professor Frank H. Loud in handling the apparatus. The object sought was to determine the extreme length of the coronal streamers and to search for any intra-mercurial objects.

My equipment consisted of a 4½-inch Cooke refractor with a photo-visual objective of focal length 81·8 inches; and a polariscopic camera, in which a double-image prism was mounted in front of an objective of aperture 1 inch and focal length 36 inches. The camera was attached to the declination axis of the telescope close to the counter-weight. This apparatus was loaned by the Dominion Astronomical Observatory, Ottawa, and thanks are due to Dr. Otto Klotz, the director, for his cordial assistance. Dr. Klotz and I had been asked by the Council of the Royal Astronomical Society of Canada to observe the eclipse on behalf of the Society. He went to Denver where, as mentioned above, dark clouds covered the sun, but I chose Matheson. I did so because prospects for a clear sky seemed to be as good there as at any place, it appeared to be quite accessible, and also it might be better to go where there would not be so many observers as at stations farther west.

As soon as possible, application was made to the Government at Washington for permission to have the apparatus enter the U.S. free of duty; and after some delay instructions were given to the Collector at Detroit to admit the goods free under bond. They were shipped on Tuesday, May 14, and through the personal interest taken in my expedition by the Agent of the Canadian Express at Toronto and the General Agent of the National Express at Detroit, the boxes containing the instruments went forward without delay and reached Matheson on Sunday, the 19th. Here Professor Loud took charge of them and placed them in safe storage.

I left Toronto on May 31, at 6 p.m. and reached Matheson at 4 p.m. on Sunday, June 2. I found that my boxes had already been taken to the summit of the hill and three small piers for the telescope had been constructed. I had brought oil-

cloth to protect the instruments from rain, but was informed that it was even more important to shield them from the wind which at times blew almost a hurricane over the exposed site. However, by good fortune, I obtained the services of two carpenters, one of whom with his own team of horses carted the lumber from the village, and by noon of Monday the shelter was complete. During the afternoon the telescope was unpacked and erected.

On Tuesday afternoon, June 4, Professor Loud, his son Mr. Francis M. Loud and Mr. Hartley arrived with the Colorado College outfit. They had come by motor, a distance of 56 miles. All morning the weather had been fine and the sky a beautiful blue, but soon after their arrival a very violent wind, rain and hail storm broke upon us and lasted for about one and a half hours. It tested our temporary houses but they remained standing.

On Wednesday, Mr. and Mrs. P. F. Whisler, of Jacksonville, Ill., former students of Drake University, joined the party. On that day, as usual, the sky was clear in the morning, but at noon black clouds came up, drops of rain began to fall and I hastily covered my instruments. The dark sky lasted until about 4.30 p.m., when the sun burst forth as brightly as ever, and I was able to complete the adjustment of the instruments.

By Thursday afternoon the arrangement of the apparatus was complete enough for us to rehearse our program. The chronometer was placed on an improvised table in a central position and electrical wires were led to operate signals at each equipment. The proceedings were as follows. Five minutes before the moment for beginning, "Time!" was to be called by Mr. Whisler, and Miss Gushee was to watch for the appearance of the corona. At the instant that she saw it she was to shout, "Go!" and to strike with a hammer on an empty barrel; and immediately Mr. Whisler was to count in a loud voice the seconds as ticked off by the chronometer — one, two, three, ... until the eclipse was over. In this way each observer could regulate the beginning and the duration of his exposures. As I wished to take photographs both with the tele-

scope and the polariscope, I was glad to accept the offer of Mr. F. M. Loud to assist me. He took charge of the former and I of the latter. During the remaining days our drills were repeated many times until at last we were able to go through the program with precision.

On Friday Mr. Charles C. Plitt, Professor of Botany in the Baltimore City College, Baltimore, Md., joined us. He had come all the way from Baltimore to see the eclipse, having chosen Matheson as the most promising place. At this time, however, our hopes of success were very slight. Day after day, at the time for the total phase, the sky was covered with clouds, especially thick in the west; but learning that Colorado was the despair of the weather forecaster and that the condition of the sky could not be predicted five minutes in advance, we did not give up.

Saturday, the day of the eclipse broke fine, and again our spirits rose, but by noon the ominous cumulus clouds appeared. At 2.30 p.m., "summer" time, they became denser and the sky grew darker. At times great cloud masses entirely obscured the sun. However at 4.13 they thinned out sufficiently for first contact to be seen clearly.

The computations of the times of contact for our station were supplied by Mr. Pettit, as follows:—

	Summer Mountain Time			
	h	m	s	
First contact	4	13	42·6	
Second contact	5	23	50·7	(beginning of totality)
Third contact	5	25	19·2	(end of totality)
Fourth contact	6	28	3·7	

The first contact was observed by Messrs. Pettit and Morehouse by projecting upon a sheet of paper the image of the sun as produced by the 3-inch finder of the large refractor. Their observation made it $7^s{\cdot}2$ later than the computed time. Like many others, I looked for it through smoked glass but I could not detect it until 10^s after they had announced it. The other contacts were observed within 1^s of the computed times.

Then there was a wait of an hour for the total phase. Many people had come to our station from all directions, perhaps 100 automobiles being gathered on the hill. All continued to watch the thinning solar crescent—and the thickening clouds. During this weary wait we were treated to a novel diversion. A rabbit appeared on the west side of the hill, and to the great amusement of the crowd three men on motorcycles attempted to run it down. The nimble-footed animal circled about for almost ten minutes, and when nearly exhausted ran into a friendly ravine over which the machines could not pass.

At 5.18 "Time!" was called, though the sun could be seen only dimly through the clouds. Soon after this the darkness began to be felt, much as though a great thunderstorm was approaching. But, to our great joy, just as the bright crescent was about to disappear, the clouds parted as though curtains were rolled back, and the sun shone clearly! The 'shadow bands' were very pronounced; through the cracks in our shelter Mr. Loud and I could see them sweeping past. Then Miss Gushee, catching sight of the corona cried "Go!" and Mr. Whisler began to count! There was the silence of awe amongst the onlookers and the astronomers were busy carrying out their programs. During the exposures we gazed on the corona, but we had to keep a strict account of the passing seconds. At "86" the sunlight shot out from behind the moon and the eclipse was over! Then the crowd surged within the fenced-off enclosure and the hill became alive again.

The corona was clearly seen in all its beauty. At least three great prominences were visible to the naked eye. A great streamer above the sun could be traced for, at least, two solar diameters (say, 2,000,000 miles) while there were two somewhat shorter, though very prominent ones, below. An interesting feature of the eclipse was the sudden appearance of Jupiter which 'popped out' just to the east of the sun as totality was announced.

A photograph of the corona is shown in Plate X. To me the long streamers on opposite limbs seem to indicate not a typical

maximum corona such as seen in 1893 and 1905. From it I would have judged that the maximum had passed by perhaps a year or more, and yet for months before and during the week of the eclipse there were some splendid spots on the sun, and Director Hale in his Annual Report of the Mount Wilson Observatory for 1917, refers to "the prolonged activity of the sun, hardly yet at its maximum."

After totality the clouds promptly returned and they gradually increased in density until at 6.28, the time of the last contact, the position of the sun could hardly be detected at all. Soon after this I began to pack up, and before noon of the following day my boxes were ready for shipment. Although they had made the outward journey in less than six days, they were more than a month in coming back.

As stated above, photographs were made both with the telescope and the polariscope, and the exposures of the former were made to conform to those of the latter, except that one was to be of double length. They were as follows :—

Telescope	Polariscope
5 sec.	5 sec.
46 "	20 "
	20 "
5 "	5 "
6 "	6 "

The rest of the time of the total phase was required to change the plates and films.

With the telescope the 46-sec. exposure was too long and the plate was a failure. The others were successful, though the last one shows a trace of the returning sun. I think the first negative the best.

The photographs with the polariscope were not so successful, though there has not yet been sufficient time to examine them critically. It seemed impossible to obtain a clear sharp image with the instrument.

Professor Plitt observed Baily's Beads, using the 3-inch finder. They made their appearance six seconds before totality

was called. There were at least 25 visible, and they were yellowish in color.

The 'flash' spectrum was observed by Mr. Donald Smith who reported as follows :—

"The reversal of the Fraunhofer lines was observed at the instant preceding and again at the instant following totality. The bright lines flashed out suddenly and lasted for approximately one second at each of these observations. The lines in the red and the blue-green (probably due to hydrogen) and in the yellow (probably the sodium lines) were most conspicuous. There were a large number of small lines in yellow and yellow-green especially. A faint continuous spectrum served as a background. The instrument used was a small ocular direct-vision spectroscope and the dispersion was not very great."

Mrs. P. F. Whisler observed the Shadow Bands and her statement is as follows :

"Shadow bands were very distinct and plainly visible just before and after the period of totality. They were black and white, each about one inch to one and one-fourth inches in width, and travelled in a direction of north-east and south-west at about a 45° angle. They appeared by the hundreds and passed very rapidly, resembling ripples or waves on water. They passed so rapidly I could not even guess at their number per second. These shadow bands were one of the many beautiful and interesting sights to be observed during the eclipse, and in both instances passed in the same direction and at the same angle. They were visible for a very short period, perhaps two or three seconds on each occurrence."

On one or two evenings during the week Professor Morehouse had allowed visitors to our station to see Saturn, the Cluster in Hercules and other celestial objects. This privilege seemed to be highly valued, and so he announced that if Saturday evening should be clear he would adapt his telescope for visual observations and put it at the service of any one who might come. The evening did become clear—as most of them did by 10 o'clock—and a large number were able to observe

interesting bodies in the sky through this fine instrument. Next day it was dismounted and packed for shipment back to Des Moines.

In concluding this account, I wish to express my gratitude to the Council of the Royal Astronomical Society of Canada for affording me the opportunity to observe this eclipse and to the Governors af the University of Toronto for contributing to the cost of transporting and erecting my instruments.

NOTES ON THE SPECTRUM OF NOVA AQUILÆ NO. 3

By J. S. Plaskett

SIXTY spectra of the Nova have been obtained here with the spectrograph used with a single prism giving linear dispersion at H_γ of 35 A. per mm. The measurable region extends from $H\beta$ well into the ultra-violet so that 19 of the hydrogen series were measured on one plate.

The spectrum has apparently followed fairly closely the usual developments taking place in novæ but has shown some rather singular features. The first spectrum obtained here on June 10 showed numerous rather broad and diffuse metallic and hydrogen absorption lines and also hydrogen emission, though the latter was not marked. The metallic absorption first became narrower and gradually disappeared, and hydrogen emission and absorption increased. Metallic lines disappeared about June 17, hydrogen absorption, doubled on June 15, became most marked on June 19, when 19 of the H series were measured, and then became fainter, disappearing on June 27 as emission became stronger. Hydrogen absorption in approximately the same position reappeared on July 1, disappeared on July 11, reappeared for a day or two on July 15 and absorption, at this displacement from normal, has not since appeared.

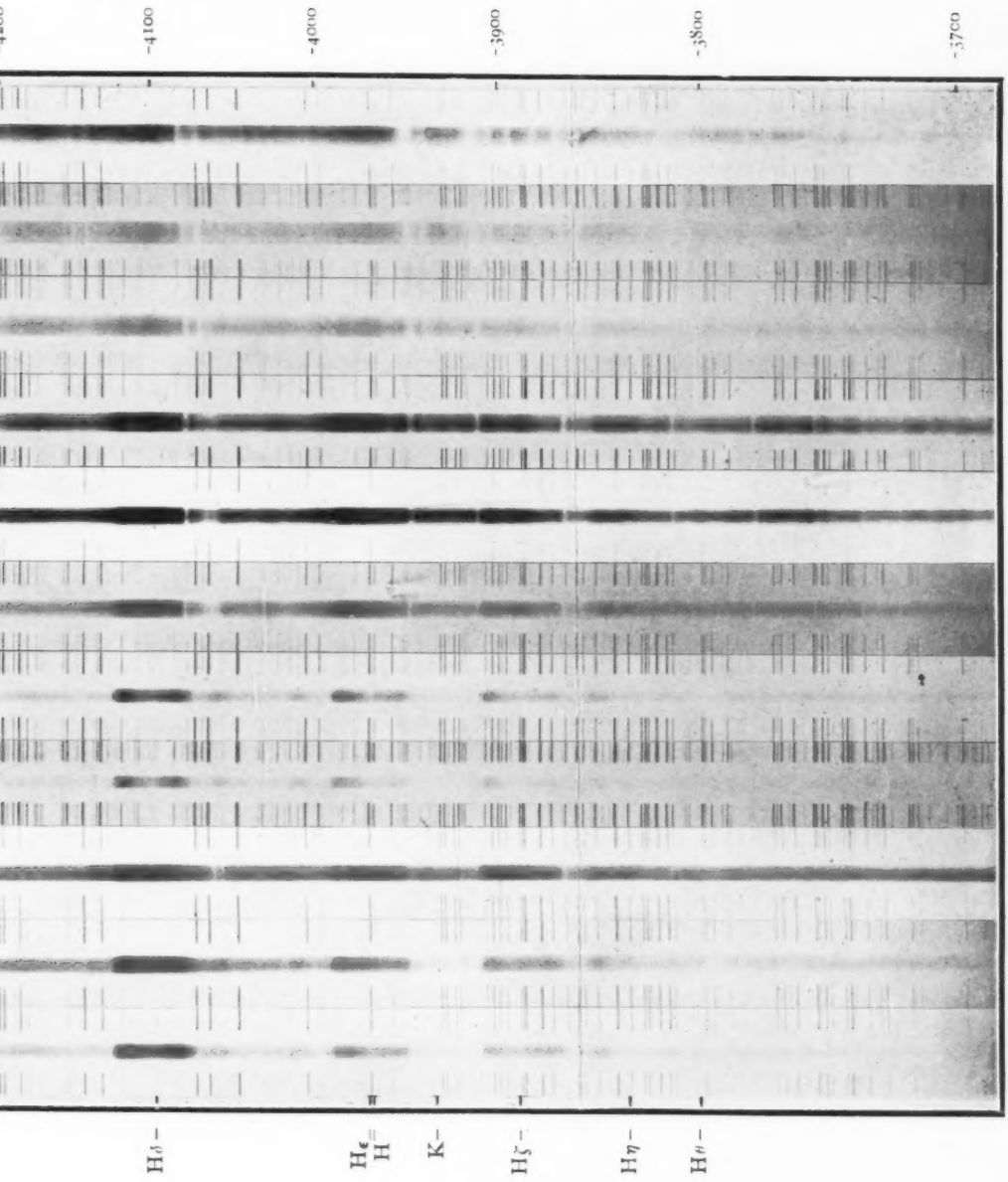
The spectrum indicated a change towards the nebular stage about June 20 when λ5007, λ4685, λ4363 began to show. On July 11 the nebular stage was strongly marked and since, up to August 5, not much change in relative intensity of nebulium and hydrogen lines has occurred.

There have been numerous and sometimes sudden changes in the relative intensity of emission and continuous spectrum, which will probably prove to be coincident with changes in apparent magnitude, although I have not at hand any photo-

SPECTR

Taken at the Dominion

PLATE XI.



PECTRA OF NOVA AQUILÆ

minion Astrophysical Observatory, Victoria, B.C.

metric measures, and, at the date of writing, August 5, the light from the star is apparently almost entirely emissive in character.

The most curious features about the spectrum however, are the behavior of the absorption lines especially hydrogen, the displaced enhanced metallic lines, and calcium.

Hydrogen, as in all novæ, is probably the most striking feature of the spectrum, and although the emission has hitherto not been as complex as in previous novæ, the behavior of the absorption lines has been exeeedingly interesting. The emission bands, weak at first, have been abruptly ended at the violet side in many spectra, the dates of appearance and disappearance being given above, by strong, generally sharply defined and moderately narrow lines at distances proportional to the wavelength and increasing at $H\gamma$ from about 20·5 A. on June 10 to 25·4 on June 24. No hydrogen absorption was visible again until July 1 when very narrow lines, doubled from July 2 to July 6 appear at 24·2 A. and 25·8 A. respectively to the violet of the normal positions at $H\gamma$ and correspondingly displaced at $H\delta$, $H\epsilon$, and $H\zeta$. These absorption lines are not present on July 11 and 12 but reappear as single lines on July 16 at 24·2 A. to violet. This series has not since appeared although there are some absorption lines within the emission bands on some of the later plates but displaced by very much smaller amounts and not forming a continuous series as the ones just described. From June 10 to June 15 inclusive a second hydrogen absorption about 33 A. to the violet at $H\gamma$ appeared, diffuse at first, narrowing and sharpening down till June 15 when it was measured from $H\beta$ to $H\mu$. No traces of this second absorption are present in the spectrum of June 17 or later.

As announced in a telegram to Professor Pickering, the measured positions of these lines agree with computed positions by Balmer's formula, changing the constant from 3646·13 to 3625·78 for the first, and 3618·4 for the second component on June 15. The residuals between computed and measured positions for 15 of the broader and 7 of the narrower components average 0·15 A. and if 5 rather discrepant ones are omitted,

the average residual is only 0·06 A., a remarkably close agreement. The constants determining the positions of the principal violet absorption series, which is practically 3629·0 on June 10, 3625·8 on June 15, diminishes to 3624·8 on June 24 and then jumps suddenly to 3625·8 when the closely doubled lines appear, and remains practically constant so long as the absorption series is present. On June 19 no less than nineteen consecutive *H* lines, beginning at $H\beta$, were measured and three more were visible. The average deviation of the computed positions, Balmer constant 3624·99, of the middle thirteen of these lines from the observed was only 0·07 A., and of nine only 0·04 A., showing that they are undoubtedly due to hydrogen, displaced by some unknown and identical cause from their normal positions.

The displacement of many enhanced metallic lines which was discovered by Messrs. Adams and Joy, of Mt. Wilson and announced as 23 A. at λ4500 has been fully confirmed in the spectra obtained here between June 10 and June 15. The positions of some 65 metallic lines identified chiefly as due to *Ti*, *Fe*, *Cr*, *Sr*, *Sc*, *V* have been measured on these plates, and it has been shown beyond doubt that the displacements are also proportional to the wave-length, are exactly the same as those of the hydrogen absorption and increase from spectrum to spectrum in exactly the same way. These displacements must evidently all be due to the same cause but what the cause is cannot be determined. Although the displacements follow the same law as if they were velocity shifts, it seems to me very unlikely that such enormous velocities as 1400 km. per sec. on June 10 increasing to 1750 on June 24 could be present. A further evidence that it can not be due to velocity is given by the second narrow absorption series of seven lines, also unmistakably due to hydrogen, whose shifts would correspond to a velocity of 2300 km. on June 15; that is to say the absorbing hydrogen would have two different velocities 1675 and 2300 km. per sec. at the same time.

When these displacements so exactly follow the Balmer law for hydrogen, and are of the same amount for the enhanced lines and also for calcium as will be seen below, it seems more likely

that they are due to some physical cause acting in the same manner on the molecules of all these elements — what the action is can only be speculated on — than to velocity.

Perhaps the most remarkable behavior of the gases is shown by the *H* and *K* lines of calcium which take three forms:—

(1) Emission, not very strongly shown, but undoubtedly present in some spectra and of similar width and position to the hydrogen emission.

(2) Displaced absorption lines, that of *K* showing always when the displaced hydrogen absorption shows and to exactly the same amount and that of *H* generally clearly separated from the H_ϵ absorption, by which it differs in wave-length by about 2 A.

(3) Very narrow and sharp lines *H* and *K* nearly in their normal position and present in most of the spectra, even when the hydrogen and other calcium absorption did not show. These lines are very accurately measurable and are apparently constant in position. They show some indications of a small cyclic change in velocity but this is so close to the probable error of measurement that it can not be regarded as by any means established. The mean value of the velocity obtained from these *H* and *K* lines on 17 plates reduced to the sun is $19{\cdot}7 \pm 0{\cdot}4$ km. per sec. Considering the velocity as constant, the probable error of a plate as determined by the measure of these two lines is 1·7 km. per sec. The early plates gave a velocity of about 17 km., which increased to 23 in about 10 days, dropped to 19 and increased again to 23, but although the lines agree very well and can be accurately measured, the difference is not sufficient with low dispersion to definitely indicate variation in velocity and we may state that this absorbing calcium is moving towards the sun at about 20 km. per sec.

It seems hardly reasonable to believe that the emissive calcium vapor, that giving the displaced lines whose position changes in a week from 20 A. to nearly 25 A. to the violet of the normal position, and that giving the narrow sharp lines, constant in position and with a velocity towards the sun of 20 km. per sec.

can be directly connected with the same body. The behavior of these stationary *H* and *K* lines is similar to that observed in numerous early type binaries where the large velocity variation given by the diffuse hydrogen and helium lines is not shared in by the sharp *H* and *K* lines. The conditions here would even more certainly seem to indicate that the light from the star is shining through a layer of relatively cooler calcium vapor which is undisturbed by the tremendous cataclysms occurring in the star. The calcium line 4226·9 has been measured on 5 or 6 plates between June 18 and June 26 and gives a velocity about 15 km. per sec. more positive than the *H* and *K* lines but it is not so sharp nor persistent as they are.

There are a number of other singular features about the spectrum which may be just mentioned. A line whose measured position is about λ4210 appears coincidently with the displaced hydrogen and the true wave-length is probably hence about λ4233 and is probably due to what Lockyer calls proto-iron. Similarly there appears to be an emission band corresponding to the proto-carbon at λ4267. Another curious feature is a pair of very broad diffuse lines to the violet of H_δ which appear and disappear and reappear again in a startling manner. The wave-length of the one decreases from λ4065 to λ4060 and of the other from λ4060 to λ4054. Their centres are about 6 A. apart and they occasionally merge into one very broad absorption band. No reasonable identifications for these lines have been found.

From measures of broad emission bands on several sprectra and comparison with the several hydrogen bands whose normal wave-lengths are known, the wave-length of some of the nova and nebular bands have been fairly well determined. For example N_1 5006·9; N_2 4959·4; 4685·4; 4641·0; 4605·2; 4471·5; 4415·0; 4363·4, etc., but these measures can probably be improved by following the star closely and catching it when the emission is well defined. It is proposed to obtain spectra at frequent intervals as long as the star can be followed here and this note is preliminary to a fuller discussion of the spectrum when complete data have been obtained.

The accompanying reproduction (Plate XI.) of a number of spectra of the nova on different dates shows clearly the great changes taking place in the spectrum as it developes from the absorption line type to the nova type with strong hydrogen, 4641, and helium emission and the gradual appearance and increase of intensity of the nebular emission, particularly N_1 5007, 4685 and 4363.

The hydrogen absorption series is also well shown on a number of these spectra, normal and displaced *H* and *K*, and also the broad pair of lines to the violet of H_δ. These spectra are reproduced in the negative form which seems to me more suitable than the positive, especially to those accustomed to examine spectrum negatives. The scale of enlargement over the original negatives is 6·54 times.

DESCRIPTION OF SPECTRA

It is interesting to note the development of the spectra in this series, and a few notes may help to point out the most striking features.

On June 10, the spectrum is mostly absorption with displaced metallic and hydrogen lines with emission relatively weak at H_β, H_γ, H_δ, H_ϵ.

On June 11, the metallic lines are narrower and sharper and emission relatively stronger.

On June 14, only a few metallic absorption lines are left, the hydrogen emission is still stronger and helium emission bands at 5017 and 4923 are quite prominent. The nova band at 4641 is also beginning to appear.

On June 15 there are still a few metallic lines, including the stationary *H* and *K* of calcium which are present in the majority of the spectra, but the feature of this spectrum is the much strengthened hydrogen and nova emission and the long broad and narrow displaced hydrogen series.

On June 19, the narrow hydrogen absorption has disappeared, the broad is sharper and extends almost to the theoretical limit and there is a great further strengthening of the

emission. In these two last spectra particularly, the displaced *H* and *K* are well shown, *H* and H_ϵ being well separated. The helium emission to the red of H_β is also prominent.

Except an increase in the relative intensity of emission as compared with continuous spectrum, there is not much change on June 22, but on June 23 it is practically entirely emission with neither continuous spectrum nor absorption lines. In this spectrum the nebular stage begins to show by emission at 4685 and 4363 and N_1 5007.

On June 27 the change is carried further still, there being neither lines nor continuous spectrum.

On July 6, there is again both continuous spectrum, the displaced hydrogen and calcium absorption and the broad absorption pair at 4060, 4054 of which traces are seen in some of the earlier spectra especially June 19, though further to the red.

On July 23, it is again mostly emission with no absorption lines and the nebular spectrum is now much stronger. N_1, N_2, 4685 and 4363 are getting nearly as strong as 4641 and the hydrogen emission, and this change is carried still further on the plate of August 5 where the nebular lines are relatively still more strong.

Dominion Astrophysical Observatory,
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LIGHT PRESSURE

By Otto Klotz

A FEW elementary statements, computations and deductions on the pressure exerted by light may be of interest to the readers of the JOURNAL. Light pressure is used in the sense of an effect of radiant energy. According to the electro-magnetic theory of light every radiation falling upon a body exerts a pressure on it, as was shown experimentally by Lebedew. In other words, every radiation striking a body tends to push it, and the action is most effective when the radiation is normal to the surface. Furthermore, the pressure is proportional to the radiation, and is inversely proportional to the square of the distance from the source of radiant energy. We may illustrate the latter by saying that the light pressure at the surface of the sun is about 46,000 times that when it reaches the earth, as the distance to the earth is about 216 times the radius of the sun, the pressure behaving as if the radiation emanated from the centre of the sun.

The next point to make is, that pressure is concerned only with the surface acted upon, and not with the mass, as gravity is, of the body or particle upon which the pressure is exerted. In this last sentence lies the essence of the elementary investigation it is intended to follow.

We shall deal with the sun as the radiant body and source of energy. The constants of the sun are pretty well known. Let us take a black spherical particle at the surface of the sun ; it is subject to the force of solar gravitation and to light pressure acting in the opposite direction to the former. Let us suppose that gravitation is n times greater than the light pressure. Now let the radius of the particle be halved ; the result will be that the pressure is decreased to one quarter, as it is dependent upon the area acted upon, while the gravitational effect is diminished

to one-eighth, as it is dependent upon the mass, which varies as the cube of the radius. It hence follows that the ratio n has been decreased to $n/2$. And so we can go on reducing the dimensions of our particle until n becomes less than unity, that is, until the light pressure exceeds the gravitational effect, and the particle is pushed away from the sun against solar gravity into space.

We shall now evaluate the result for the limiting condition of light pressure overcoming the solar attraction. The radius of the sun, R, is taken at

433200 miles or 697170 km. $= 69717 \times 10^5$ cm.

The mass of the sun is 324440 times that of the earth. The ratio of solar to terrestrial radius is 109·4. Taking gravity or terrestrial acceleration at 32·18 ft., we readily find for the sun $G = 870$ ft. or 265 m., or 265×10^2 cm. per sec. per second.

Use has been made in previous papers appearing in the JOURNAL by the writer of expressing equations in dimensions, that is, in terms of the fundamental units of mass, length and time, $M L T$, and it will be done in the following whenever it is considered to assist in clarifying the concept of equality in the particular equation.

The velocity of a body falling from infinite space to the sun is given by $v = \sqrt{2\,G\,R}$ or $L\,T^{-1} = (L\,T^{-2}\,L)^{1/2}$. Substituting the above values we get $v = 608$ km. per second or 608×10^5 cm. The kinetic energy of the particle on arriving at the surface of the sun is $\frac{1}{2}\,m\,v^2$, in dimensions $M\,L^2\,T^{-2}$; obviously if the particle is to be projected into infinite space the work done, $M L^2\,T^{-2}$, force into distance, or rate of work into time, must equal the above energy. This work and energy we shall subsequently equate.

The rate of emission of energy of any radiating body for all wave-lengths is expressed by $S = C\,T^4$, showing that it is proportional to the fourth power of the effective absolute temperature of the body, where C is a constant. This is Stefan's law. Radiation exerts a pressure, which is measured by the quantity of energy contained in a unit volume of the medium transmitting

it. Expressing this in dimensions, pressure $= M L^2 T^{-2}/L^3$ or $M L^{-1} T^{-2}$, which is identical with the usual definition of pressure equaling force divided by area or $M L T^{-2}/L^2$. The above general equation $S = C T^4$ may be written in the form*

$$S_t = \frac{a c}{4} (273° + t)^4$$

where $a = 7{\cdot}28 \times 10^{-15}$ ergs and $c = 3 \times 10^{10}$ cm., the velocity of light, when we express the radiation from one square centimetre per second. In dimensions we express this by

$$M L^2 T^{-2}/L^2 T = M T^{-3}.$$

The effective temperature of the surface of the sun is taken at 6000° C. or 6273° in the absolute scale. Substituting in the above we obtain for the energy of radiation of the sun for 1 sq. cm. per second, $S_t = 84 \times 10^9$ ergs.

We have now the necessary material or data for equating. We ask what must be the size of the black spherical particle. the density of which we shall assume to be unity, that will just be balanced, or on the verge of being propelled, by the effect of solar radiation. If S_t expresses the energy at the surface of the sun from 1 sq. cm. per second, then the energy for unit distance from the centre is $S_t R^2$ and for distance

$$D \text{ is } S_t \frac{R^2}{D^2},$$

and energy received per second by a sphere of radius r at distance D is

$$S_t \frac{R^2}{D^2} \pi r^2 = M T^{-3} L^2 = M L^2 T^{-3} =$$

rate of work, equivalent to horse power.
Hence work done in time $d t$

$$= S_t \frac{R^2}{D^2} \pi r^2 d t.$$

*This formula and the value $a = 7{\cdot}28 \times 10^{-15}$ may be found in Masius' translation of Planck's "Theory of Heat Radiation," p. 64.

The total work done on the particle projected from the sun to infinite space is

$$\int_{D=R}^{D=\infty} S_t \frac{R^2}{D^2} \pi r^2 \, d t.$$

Introducing c the velocity of light we transform the above to

$$\int_{D=R}^{D=\infty} \frac{S_t}{c} \frac{R^2}{D^2} \pi r^2 \, c \, d t, \text{ where } c \, d t = d D$$

or

$$\int_{D=R}^{D=\infty} \frac{S_t}{c} R^2 \pi r^2 \frac{d D}{D^2} = S_t \pi r^2 \frac{R}{c}.$$

Now we equate the work done with the energy as intimated above.

Hence

$$S_t \pi r^2 \frac{R}{c} = \tfrac{1}{2} m v^2.$$

The density ρ, does not appear in the deduction for mass, as the density is assumed as unity, that of water.

In dimensions the above equation is

$$M T^{-3} L^2 L L^{-1} T = M L^2 T^{-2}.$$

The above expression becomes

$$S_t \pi r^2 \frac{R}{c} = \tfrac{1}{2} \tfrac{4}{3} \pi r^3 v^2, \text{ or } r = \frac{3 S_t R}{2 c v^2}.$$

Substituting the values given for

$$S_t, R, c \text{ and } v \text{ we have } r = \frac{3 \times 84 \times 10^9 \times 69717 \times 10^5}{2 \times 3 \times 10^{10} \times (608 \times 10^5)^2},$$

hence $r = 7{\cdot}914 \times 10^{-5}$ cm.

$= {\cdot}00079$ mm.

$= {\cdot}79\ \mu$, or the diameter $= 1{\cdot}6\ \mu$, the value found by Arrhenius and others. This magnitude of $1{\cdot}6\ \mu$ is about 2·7 times that of the D line in the solar spectrum, taken at 5980 Angströms or ·5980 μ. If the diameter of the particle were ·00016 mm., the repulsive force would be theoretically ten times

greater than that due to solar gravity. There is necessarily a limiting value for the maximum effect of the radiating pressure dependent upon the diameter of the spherical particle and upon the wave-length.

We have found the value for the radiation of the sun per sq. cm. per second to be 84×10^9 ergs, in dimensions $M\,T^{-3}$. The pressure will be found by dividing by the velocity of light, —by the rate of propagation of the energy. Hence

$$\rho = 84 \times 10^9/3 \times 10^{10} = 2{\cdot}8 \text{ dynes},$$

in dimensions $M\,T^{-3}/L\,T^{-1} = M\,L^{-1}\,T^{-2}$ = pressure.

Or we may equate the pressure on the surface of the particle, with its mass into solar gravitation ; in dimensions $M\,L^{-1}\,T^{-2}\,L^2 = M\,L\,T^{-2}$ = force, or in this case weight at the sun.

Hence, $\rho\,\pi\,r^2 = m\,G = {}^4/_3\,\pi\,r^3\,G$, taking as before density 1,

$$\rho = {}^4/_3 \times 8 \times 10^{-5} \times 265 \times 10^2$$
$$= 2{\cdot}8 \text{ dynes as before.}$$

Expressing the absolute units 2·8 dynes in gravitational units, we divide by $g = 981$ cm., hence obtain 2·8 milligrammes as the pressure per sq cm. That is a black body on the surface of the sun experiences a pressure of 2·8 milligrammes per sq. cm. due to solar radiation,—temperature of sun's surface 6000°C or 6273° absolute.

The pressure due to solar radiation at the distance of the earth would be 2·8 milligrammes divided by $(216)^2$, or $6{\cdot}0 \times 10^{-5}$ milligrammes. Perhaps this latter becomes more understandable if we give the area upon which the pressure is one milligramme which is simply the reciprocal of the above, that is 1·7 sq. metres, or a square with 1·3 m. to a side, or 4 ft. 3 in.

A person of average size would hence experience a light pressure of a little less than a quarter of a milligramme when shone upon by the sun,—or less than ·004 grain, one two hundred and fiftieth of a grain, tending to push him over.

About ten years ago Arrhenius published his "Worlds in

the Making," and in the last chapter he discusses the possibility of the transference of life throughout the universe, partly under the influence of light pressure. He makes the statement that according to Schwarzschild's computations the greatest effect of solar light pressure would be manifested on spherical particles of ·00016 mm. diameter, the magnitude last given above.

It is understood that we have spores of the lower organisms of that minuteness. However the discussion of "panspermie" is outside of this brief note.

DOMINION ASTRONOMICAL OBSERVATORY,
OTTAWA, CANADA.
May 1, 1918.

VENUS, JUPITER AND OTHER THINGS

By A. R. Hassard

ON Sunday morning, July 28, 1918, I saw the planets Venus and Jupiter in the eastern sky just shortly after their conjunction. The time of my observation was about 4 o'clock, by the new Government time. Venus was closer to the horizon than Jupiter, and the two planets were not much more than a moon's breadth apart. Venus was very bright and scintillated with its customary splendor, while Jupiter with its slightly ruddy appearance presented a striking contrast to the silvery whiteness of its lustrous companion. Conjunction had occurred about twenty-four hours before my observation, but I have often noticed—for reasons which, of course, are obvious to astronomers,—that the conjunction of two planets or astral bodies is not always the actual moment of their nearest proximity. I happened to awaken a little later the same morning, and the hour was then approaching to sunrise. The eastern heavens were growing ruddy with the glow of approaching morning. Jupiter was becoming paler as dawn drew near. But Venus shone with even a more silvery lustre than it had done when I first began observing the two planets hanging low in the eastern sky.

The sunrise the same morning was wondrously exquisite. The sun came up not like a ball of gold but like a circle of the deepest and flaming crimson it is possible to conceive. The risen sun tinged all the sky with its rich color, and a pathway of rippling crimson stretched across the lake from my window towards the birthplace of the Lord of Dawn. A few clouds, light and fleecy, still hung in the east, and they too were touched with the ruddy glory of the rising sun. Even the trees, houses and grass were impressed by the color of the Monarch of the Day.

I first saw the new star in Aquila on Monday evening, June 10th, two days after its discovery was announced to the world. It was then as bright as Altair, that is to say, it was easily of the first magnitude. It was located about 5° to the south of the splendid double, Theta Serpentis. The constellation of Aquila at that point intrudes itself upon the constellation of Serpens, so that there is a break in the constellation of Aquila in the path of a straight line joining Altair and the new star. For several nights the new star shone with almost the lustre and brightness of Altair, then there came some nights of cloudiness, when that part of the heavens was invisible. When next the new star was seen it had perceptibly diminished in brightness, until it became almost fainter than the third magnitude, in fact it was of almost equal brightness with Theta Serpentis.

As I have stated in former notes, I have an 8-inch reflecting telescope of my own construction at our summer cottage. We use it extensively in the day time to view the neighboring and distant points of interest. With it we have become very familiar with all the spots of interest upon the opposite shores of a bay which our cottage overlooks, and which is about two miles in width. The shuttered windows, the terraced lawns, the wide-armed wind mills, the boat houses, the grassy slopes, the far off fields now changing from green to gold, the sailing vessels, the launches, the canoes, the sandy shores have become familiar to all who have used the instrument frequently. Even the lake gulls resting on the top of the red and white striped buoy nearly a mile away have come in for a share of attention. Much more than in the city is such an instrument an object of usefulness in the daytime. and the moon and other celestial bodies receive, in the hours after the sun has set, a measure of large and interesting attention.

On Friday night, August 2, 1918, there was a wonderful display of aurora in the northern sky. A most interesting feature of the outburst took place at about 11.15 o'clock at night. At that hour a wonderful band of white light, shaped in part like the tail of a comet began to stream across the entire

sky from north-west to south-east. This band was about 2° or 3° wide at the point where it dipped below the north-western horizon, and broadened until, at the point overhead near where the white star Vega was immersed in its light, to a width of about 5°. From the zenith it slightly narrowed, until it was only about 2° or 3° in width at a distance of about 10° above the south-eastern horizon. The whole appearance was as if some giant comet rushing close in upon the sun had suddenly made its appearance in the midnight heavens, with its head or nucleus buried fathoms deep behind or below the star crowned fringe of the western sky, and its mighty tail stretching a distance of 150° far across the luminous firmament, cutting the slightly less luminous Milky Way almost at right angles, and filling the entire heavens with a glory that was not only unusual but also mysteriously sublime. Slowly the vast band of white light moved to the southward, almost eclipsing the bright star Arcturus, and the southern boundary of the constellation Lyra. This slow movement continued for twenty minutes, the band being all the time of intensely white brightness, and being of a constant width as well. Then gradually the band began to grow dimmer, and also to break up into fragments, whereupon almost at the zenith the band dissolved into about ten short parallel bands, each about 5° in length, and of less than a degree in breadth, and lying diagonally across the line where the band had lately lain. A little later and there remained but faint traces of the white streamer which had so lately flung its lustrous splendor across the heavens. Before the breaking up occurred, however, the band had extended to the eastern horizon, dividing the entire firmament almost equally into two parts. I have seen light bands previously stretching across the heavens, but never one so vast nor so luminous as this one appeared to be.

On Saturday morning, August 3, 1918, the early eastern sky presented a very pretty appearance. Near the horizon blazed the luminous white star Venus. Higher towards the zenith, but only about 7° from Venus, shone Jupiter, and 5° still further away hung the almost wasted moon. The three objects in such close

proximity presented a spectacle of unusual occurrence, and also of unusual brilliance.

On the following morning the view would have been still more striking, for the moon then was much nearer to Venus than on the Saturday morning, but the sky just after moon-rise was clouded over, and there was no view of moon and planets.

During the past couple of weeks it has been interesting to view the planet Mars in the western sky approaching the first magnitude star Spica. Night after night these two celestial bodies have been approaching, until on Saturday night, August 2, the two bodies were about 3° apart. The night preceding, these two stars were quite plainly visible as they came together. On Saturday night the sky was clouded, and their closer approach was invisible. It had been apparent for some time, however, that the conjunction of the two stars would still show them some little distance apart, for the path of Mars is slightly to the north of Spica. Yet the presence of two first magnitude stars so close to each other as two or three degrees is a circumstance not often visible; hence its interest, if not to science, at least to curiosity.

On Saturday, August 2, 1918, at a little after the noon hour a mighty rainbow-hued ring of about 40° in diameter surrounded the sun. While the rainbow colors were faintly displayed, the entire circle was of a vivid golden tinge. Part of the circle was not so well seen as other parts, but the entire circle was visible, when one concealed the sun behind a hat or a newspaper. This circle lasted for some time, over an hour at the least, but later in the afternoon it faded away. The weather was rather cool, and at 7.20 p.m. a strong breeze sprang up, and the lake before our home was dashed very speedily into a wild fury, which continued until the morning. The weather on the following evening and at the same hour, strange to say, underwent a similar experience.

TORONTO,
August 7, 1918.

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

June, 1918

Temperature.—The mean temperature was in excess of the normal from Western Manitoba to the Pacific, and less than normal in all other portions of the Dominion. The excess was greatest, amounting to about 6°, in Southern Alberta, and the defect was greatest in the Upper Ottawa Valley and Northern Quebec, where it was from 3° to 5°. In the West the abnormal warmth resulted from a series of heat waves during the second and third weeks, whereas the first and fourth weeks were comparatively cool. From Ontario eastward the warmest periods were the first few days and the last week of the month.

Rainfall.—The rainfall of June was greatly in defect in the Western Provinces, exclusive of the extreme eastern and northern districts of Manitoba and the extreme northern districts of Saskatchewan and Alberta. In Southern Alberta the total rain of the month was very generally less than one inch, and in Southern Saskatchewan and Western Manitoba it was less than two inches. In Ontario differences from average were mostly negative, but in the extreme north and towards the Ottawa Valley the rainfall was very nearly average, and in some small districts near the west end of Lake Ontario and in Peterboro' and Haliburton Counties it was somewhat in excess. In Quebec and the Maritime Provinces the rain was in excess of the average, excepting only the extreme southwestern part of Nova Scotia.

JULY, 1918

Temperature.—In no part of the Dominion did the mean temperature of the month differ very greatly from the normal, but in all the Provinces exclusive of the Maritime Provinces, some portions of the month were much above average and other portions much below—the negative departures nearly balancing the positive departures. The largest negative departure, about 4°, occurred in Southeastern Saskatchewan, and the largest positive, about 2°, in the districts of Nipissing and Algoma of Ontario. In the West the period of greatest warmth occurred about the 20th, and an unusually cold spell from 23rd to 28th. In Ontario and Quebec the weather was quite cool until the 12th, after which the general average temperature was decidedly high.

Rainfall.—In Quebec and the Maritime Provinces and in Ontario north of the C.P.R. Transcontinental Railway, the rainfall of July was in excess of the normal, while in all other parts of Canada it was in defect. The most pronounced deficiency was in Southern Alberta and Southwestern Saskatchewan, where the total was very generally less than 1·5 inches, and in the central counties of the Peninsula of Ontario, where it was less than one inch. The heaviest fall was in Northern New Brunswick, where at many points it was nearly ten inches.

Temperature for June and July, 1918

Station	June		July	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson	80	28	86	34
British Columbia				
Atlin	72	30	83	33
Agassiz	86	39	94	41
Barkerville	80	28	84	28
Kamloops	92	37	102	47
New Westminster	86	38	88	46
Prince Rupert	72	36	81	44
Vancouver	83	40	76	42
Victoria	80	42	78	46
Western Provinces				
Battleford	98	32	97	32
Calgary	90	31	94	32
Edmonton	83	31	90	29
Medicine Hat	98	35	98	42
Minnedosa	97	34	92	38
Moose Jaw	103	30	100	38
Oakbank	91	34	85	38
Portage la Prairie	99	37	94	43
Prince Albert	92	32	92	34
Qu'Appelle	97	28	99	30
Regina			95	36
Saskatoon	100	31	92	32
Souris	101	35	94	42
Swift Current	96	48	96	50
Winnipeg	94	36	89	41
Ontario				
Agincourt	88	37	92	46
Aurora	85	33	93	40
Bancroft	84	29	89	41
Barrie				
Beatrice	82	34	92	39
Bloomfield	77	32	88	46
Brantford	87	39	97	41
Chapleau	74	29	91	31
Chatham	91	40	101	43
Clinton	85	32	93	38
Collingwood				
Cottam	87	32	94	45
Georgetown	86	37	92	45
Goderich	84	37	92	46
Gravenhurst	84	40	91	46
Grimsby	87	37	95	46
Guelph				
Haliburton	88	31	93	38
Huntsville	83	34	92	42
Kenora	85	33	84	45
Kinmount			92	38
Kingston	82	40	90	50
Kitchener	85	37	94	42
London	88	36	98	41
Lucknow	81	30	91	37
Markdale	85	34	93	36
North Gower	85	30	94	40
Oshawa	86	41	91	41
Ottawa	90	38	94	48
Paris	87	38	96	43
Parry Sound	83	38	97	43
Peterboro'	80	35	95	43
Port Arthur	80	35	87	34
Port Burwell	80	39		
Port Dover	87	37	91	46
Port Stanley	83	37	86	44
Queensborough	85	33	89	40
Ronville	82	38	91	38
Southampton	83	38	89	41
Sundridge				
Stonecliffe	90	34	96	46
Stony Creek	88	39	96	42
Toronto	89	39	92	48
Uxbridge	84	37	92	42
Wallaceburg	85	28	96	45
Welland			94	46
White River	76	23	88	29
Quebec				
Brome	83	28	88	41
Father Point	76	36	74	42
Montreal	86	44	92	50
Quebec	85	38	88	49
Sherbrooke	83	32		
Maritime Provinces				
Charlottetown	80	34	84	52
Chatham	84	36	92	52
Dalhousie				
Fredericton	86	33	91	48
Halifax	86	34	86	46
Moncton	84	31	88	41
St. John	80	40	82	50
Sussex	84	32	85	45
Sydney	82	36	86	44
Yarmouth	75	34	84	50

MAGNETIC OBSERVATIONS

MAY, 1918

The Magnetic Forces, as shown by the records obtained at Agincourt and Meanook, were comparatively quiet during the month, except on the 16th and 17th when a large disturbance was in progress at both observatories. At Agincourt the disturbance began gradually, shortly after noon of the 16th in all three elements and was very active until 5 hours of the 17th and particularly so in the Horizontal Force. Up to 20 hours of the 16th the H shows a very large increase and then suddenly fell below normal to an almost equal amount and remained down until nearly the end of the storm when it gradually resumed its normal value. The Z likewise was higher than usual from the beginning to 20 hours and then suddenly diminished but not to the same extent as the H. The D magnet oscillated rapidly about its normal position at both observatories.

During this disturbance there were only a very few small sun spots to be seen, whilst on the 8th, when there was no magnetic disturbance, there was a large penumbral spot centred on the sun's surface and a large number of small spots.

AGINCOURT MAGNETIC OBSERVATIONS

Lat. 43° 47′ N.; Long. 79° 16′ W.

May, 1917		D. West	H	Z	I
		° ′	γ	γ	° ′
	Mean of Month	6 38·4	15926	58365	74 44·2
	Maximum	7 19·6	16278	58558	
	Date of Maximum	17	16	16	
	Minimum	6 02·5	15471	58074	
	Date of Minimum	16	17	16	
	Monthly Range	1 17·1	807	484	
Mean Daily Amplitude	From hourly readings	14·2	59	31	
	From means of extremes	24·1	119	64	

MEANOOK MAGNETIC OBSERNATIONS

Lat. 54° 37′ N.; Long. 113° 21′ W.

May, 1917		D. East	H	Z	I
		° ′	γ	γ	° ′
	Mean of Month	27 42·8	12990*	60584	77 53·9
	Maximum	28 54·2			
	Date of Maximum	16			
	Minimum	26 18·8			
	Date of Minimum	16			
	Monthly Range	2 35·4			
Mean Daily Amplitude	From hourly readings	16·7			
	From means of extremes	38·9			

* Disturbed on days of observation.

H and Z are given in Gammas. (1 γ = 0·00001 C.G.S.).

All results are reduced to I.M.S.

The value of I at Meanook is the mean of all the observations made during the month without regard to the time of day.

The value of H at Meanook is the mean of two observations made about the middle of the month, and the Z is obtained by the formula Z = H tan I.

W. E. W. J.

Earthquake Records by the Milne Seismograph

Toronto

Sir Frederic Stupart, Director.

P.T. = Preliminary Tremors. S. = Secondary Waves. L.W. = Large Waves. A.C. = Air Currents. Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1918		P. T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks
			h m	h m	h m	h m	h m	mm	
1856	June	2			13 41·3		13 44·0	0·05	
1857	"	3		0 23·7?	0 31·8 0 39·9	0 44·2	1 57·7?	1·3	Micros going on.
1858	"	4			4 59·7 5 11·4	5 18·9	Micros.	0·8	P. and S. masked by micros.
1859	"	4			18 02·3 18 08·0	18 12·7		1·6	Micros before L. waves.
1860	"	7	21 34·9	21 40·3	21 48·4	21 53·4	Micros.	1·3	3,610 km, Boom moved suddenly to W. at beginning of L.
1861	"	11			12 48·3	12 54·8	13 28·5	0·8	
1862	"	12			4 46·3	4 46·8	5 06·8	0·3	
1863	"	13			9 10·8		9 38·2	0·05	
1864	"	16			6 19·0		6 47·5	0·2	
1865	"	16		12 37·3? 12 39·4	12 42·3	12 46·7	13 05·1	0·2	
1866	"	21			4 45·2? 4 58·2			0·1	
1867	"	22			22 21·0 22 24·7	22 25·9	22 43·8	0·6	
1868	"	24			15 50·2?	16 02·5	16 34·8	0·1	Thickening.
1869	"	26			22 32·1	22 39·3	23 15·1?	0·4	Very gradual
1870	"	27			22 01·3	22 07·4	22 37·7	0·2	Micros going on before L.
1871	July	1			7 02·8 7 17·3		8 00·0	0·2	
1872	"	3	7 14·5? 7 16·9	7 21·9	7 30·5 7 48·6	8 04·3	9 23·7	4·3	P not defined. At 7 30 5 sudden deflection to E and then momentary pause.
1873	"	8	10 37·9?	10 48·6 10 56·4	11 14·9	11 35·6	13 41·9	1·0	9,650 km.? May be a dual eq.
1874	"	15	Micros.	0 35·0	0 41·7 0 44·2	0 44·9	1 46·7	2·4	Eureka, Cal.?
1875	"	16			20 48·1? 20 50·6		20 56·8	0·05	
1876	"	16			23 55·3		23 59·2	0·05	
1877	"	21	6 31·3?	6 40·5?	6 55·7 7 05·3	7 22·9	A.C.	2·9	Time doubtful, no cut-offs. A.C. mask phases.
1878	"	21				11 01·9?		0·1	A.C. mask phases
1879	"	23		14 27·4?	14 31·5	14 37·8	14 50·6?	0·3	S may be L. A.C. mask phases.
1880	"	24			11 56·6	11 59·7 18 03·1?	A.C.	0·2	A.C. mask phases
1881	"	29						0·2	A.C. mask phases
1882	"	31	14 48·6?	14 53·7	14 57·2	15 00·1	A.C.	1·0	A.C. going on.
1883	"	31			23 00·8?	23 09·2?	?	0·1	A.C. mask phases Time doubtful.

June 17—Light off at 16h 43m when small quake occurred at some stations.
July 14—Micros going on after 17 hours.
Sheet July 20th to 27th one mass of A.C., also 29th.

Boom period 18 seconds. Pillar inclination 1mm. = 0°·45.

VICTORIA, B. C.

F. N. DENISON, SUPERINTENDENT.

No.	Date 1918	P.T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks
		h m s	h m s	h m s	h m s	h m s	mm	
1853	June 2	13 22 25			13 22 47	13 27 22	0·1	P. may be L. phase.
1854	" 3	0 31 34		0 49 16	0 57 38	1 31 34	0·5	
1855	" 4	4 29 24		4 46 15 4 51 52	4 59 08	5 15 01	0·4	
1856	" 4	17 34 35		17 49 35	18 00 10	18 50 19	0·4	
1857	" 5				23 18 33		0·1	
1858	" 7	21 33 58	21 39 55	21 45 23	21 47 51	22 40 23	2·0	4,170 km.
1859	" 11				13 13 57	13 31 39	0·4	
1860	" 12			4 27 45	4 28 44	4 41 51	0·4	
1861	" 13				9 22 30		0·1	
1862	" 16	5 46 33	5 52 27	6 00 20	6 05 45	6 14 06?	0·2	4,120 km.
1863	" 16			12 56 43		13 01 37	0·05	
1864	" 21	4 37 03		4 39 32	4 42 00	4 49 27	0·2	1,440 km.
1865	" 22			22 31 53 22 36 48	22 44 10	22 54 57	0·1	
1866	" 24	15 29 30	15 32 57	15 38 51	15 44 15	15 59 00	0·2	2,040 km.
1867	" 26			22 10 33	22 20 57	22 30 57	0·4	
1868	" 27	21 40 28			21 52 22	22 13 11	0·2	
1869	July 1	6 32 00	6 39 52	6 53 38	7 23 39	8 06 26	0·5	6,290 km.
1870	" 3	7 05 38	7 15 48 7 17 28	7 36 22	7 47 47	9 57 42	4·0	P time determined from V. 9000 km. Probably S. America.
1871	" 8	10 46 14	10 54 36	11 08 12	11 26 05	12 58 02	1·7	6,870 km. North Peru.
1872	" 15	0 25 25	0 26 53		0 28 51	1 19 50	11·5	S may be L. 651 km. N. Calif felt at Eureka.
1873	" 16				20 50 32		0·1	
1874	" 16			23 58 24?	0 02 51	0 06 47	0·2	
1875	" 21	6 33 26	6 40 39	6 51 34	7 09 20	9 07 52	2·0	5,560 km.
1876	" 21				10 40 48		0·3	
1877	" 23			14 07 26?	14 18 15	14 36 27	0·3	
1878	" 24			11 37 34	11 51 20	12 15 56	0·2	
1879	" 29			12 01 06	12 08 36	12 23 06	0·2	
1880	" 29	17 12 36	17 24 13	17 44 53	17 59 08	18 04 34	0·5	10,500 km.
1881	" 31		15 01 49?	15 06 14	15 16 04	15 58 51	0·7	
1882	" 31			22 45 04	22 55 23	23 10 09	0·25	

Revelstoke reports slight quake on night of July 27, 1918.
Boom period 18 seconds. Pillar inclination 1mm. = 0″·54

VERTICAL SEISMOGRAPH

Date 1918	P.T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks
	h m s	h m s	h m s	h m s	h m s	μ	
June 7	21 33 48	?	21 47 48	21 49 20	?	4	
July 3	7 05 30	?	7 36 00	7 44 36	?	7	
" 8	10 45 07	10 54 13	?	11 28 43	?	3	7740 km. North Peru.
" 15	0 25 00	00 26 46	0 28 40	0 29 13	?	25	750 km. Felt at Eureka.

ASTRONOMICAL NOTES

OBLIQUITY OF THE ECLIPTIC.—In the ancient tradition—we are reminded in an abstract in *Nature* of a lecture at the Royal Institution, by Sir George Greenhill, on "The Spinning Top in Harness"—there was formerly no Obliquity of the Ecliptic, and the year was one perpetual spring. But after the Fall of Man, in the Greek legendary astronomical theory Milton has thrown into verse in "Paradise Lost"—

> Some say he bid his angels turn askance
> The poles of Earth, twice ten degrees and more,
> From the Sun's axle. They with labor pushed
> Oblique the centric globe.

No particular labor would be required, as we see with the Maxwell top, if only the polar axis projected, as the angel could move the poles by holding his finger against the axle and letting it run up. A reverse action at the Millennium will restore eternal spring.—*English Mechanic and World of Science*, August 2, 1918.

STAR CLUSTERS.—There can be little doubt that the galactic plane defined by the faint stars and by the Milky Way clouds is also a symmetrical and fundamental plane for the system of globular clusters. In other words, the distribution of clusters shows that, notwithstanding their great dimensions, they are subordinate members of the far greater galactic system. Their arrangement and the relative densities of various parts of the Milky Way clouds strongly suggest that the whole sidereal system is roughly outlined by the positions of globular clusters,

and that all known celestial objects—stars, nebulæ, clusters—are members of a single unit.

The mean diameter of the proposed system appears to be at least 300,000 light-years; its most conspicuous feature is the equatorial segment, which apparently is thickly populated with stars throughout its whole extent. From this viewpoint the Milky Way is mainly a phenomenon of depth; its extent, as seen from the sun, is something like three times as great in the direction of centre as in the opposite direction toward Auriga and Taurus. The testimony of the star frequencies in the Milky Way clouds does not disagree with the supposition of a remarkably eccentric position of the solar system.

Slipher's radial velocity observations of the brighter globular clusters indicate that seven out of eight of those with high galactic latitudes are approaching the sun (and probably the equatorial segment) with such high velocities that, unless greatly retarded, they will have entered the dense stellar regions within an interval of time which appears to be short as compared with the probable history of a stellar system. The absence of such clusters from the galaxy thus becomes the more remarkable. The globular systems nearest the galactic plane are in general the least condensed. This result and the distribution of stars in certain open clusters suggest the possibility that upon approaching the galactic regions globular clusters may be disrupted and transformed into open galactic groups.

The galactic centre as derived from the clusters is nearly at right angles to the direction of centre obtained by Walkey and Charlier from statistical investigations of the brighter stars. The stars of spectral type B, according to Charlier, form a flattened system of some 2000 light-years radius, which he identifies with the general stellar universe; the group is very small, however, as compared with the system now outlined by globular clusters, and we may assume instead that these B stars comprise a localized stellar organization.—H. SHAPLEY, *Proceedings U. S. National Academy of Sciences*, August, 1918.

J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

QUERY.

Yesterday, August 15th, just after sunset I saw a sight which was quite new to me, and I am writing to ask you whether it is often seen and what is the cause of it.

The sun had been set about twenty minutes behind the distant horizon and the sky in its vicinity was beautifully red and quite free from clouds. My wife and I were on the look-out for Mercury, who had eluded us for the last fortnight except on one doubtful occasion. Instead of Mercury, we saw three or four beams of light radiating from the already-set sun, two of them being upwards, the other two directed obliquely. I thought at first it was the zodiacal light; my wife thought it looked more like auroral streamers. The beams were fairly wide and got wider the further away one went from the sun; there was no flickering, they appeared quite steady, and extended, I should say, some twenty or thirty degrees from the sun.

Curiously enough later in the evening, say from nine to eleven o'clock, there was a good auroral display. Can there be any connection between the two appearances?—JOHN SATTERLY, Jackson's Point, Ont.

ANSWER.

The only suggestion which occurs to me is that the streamers were due to sunlight streaming through spaces between, or openings in, the clouds, though if such was the case I think Dr. Satterly would have recognized it. Can some one offer an explanation?—C. A. C.

FORMAL OPENING OF THE VICTORIA OBSERVATORY

The Dominion Astrophysical Observatory at Victoria, B.C., was "officially" opened on June 11. Dr. Plaskett and his assistant, Dr. Young, had observed the eclipse of the sun at the Lick Observatory station at Goldendale, Washington, and of those present there Director W. W. Campbell, Dr. John A. Brashear, of Pittsburgh, and Dr. Ambrose Swasey, of Cleveland, went on to Victoria, to take part in the proceedings. Many distinguished representatives of the Province of British Columbia were present. After an address of welcome by Dr. Plaskett, remarks were made by the three visiting scientists just mentioned and then Lieut.-Governor Sir Frank Stillman Barnard declared the Observatory open.

In the next number of the JOURNAL will appear an illustrated account of the completion of the great telescope. Immediately upon the receipt of the mirror the instrument was finally adjusted and put into active use. The article on "Nova Aquilæ" in the present issue is one of the first fruits and we hope to publish many more results as the years go on.

"SHADOW BANDS" AT A TOTAL ECLIPSE OF THE SUN

One of the most interesting and most puzzling features of an eclipse of the sun is appearance and motion of the "shadow bands," and probably the most detailed study of them yet recorded was made at the Lick Observatory station on June 8th last. On that occasion Messrs. John A. Brashear, Ambrose Swasey, J. S. Plaskett, Reynold K. Young and E. A. Fath, all experienced observers, gave special attention to this phenomenon, and their reports are given by Director Campbell in his account of the eclipse, published in the *Publications of the Astronomical Society of the Pacific*, August, 1918. They may be summarized as follows:—

Dr. Brashear: Bands began 30 seconds before totality. Plainly seen, moving swiftly. Brightest on preceding side. Line of crests, as determined by three rods laid on a white cloth over which they passed, in azimuth S. 39·3° W. Shadows moved from N.W. to S.E. Observations confined to appearance before totality.

Dr. Swasey: Very plainly visible both before and after totality, perhaps best half a minute before totality came and 10 seconds after totality passed. Distance between crests about 10 inches. Line of crests, or wave fronts, in azimuth S. 40° W. Motion N.W. to S.E.

Dr. Plaskett: Moving rapidly; quite prominent; crests about 10 inches apart. Azimuth of wave-crests, S. 55° W. before totality and S. 45° W. after it. Moving from N.W. to S.E. More prominent after than before totality.

Dr. Young: Visible from 15 to 20 seconds before totality to 2 or 3 seconds after. Width of shadows about 2 inches; dark, no color. From crest to crest about 8 inches. Crests more broken than could be accounted for by irregularities in white cloths spread on the ground. Bands not so plainly observed after totality. Bands about 1 inch wide when first visible and fairly faint. As they grew plainer they seemed under 2 inches, and most plainly visible 2 or 3 seconds before totality. Azimuth of wave-crests, before totality, S. 39° W.; after S. 48° W.

Dr. Fath: Bands appeared at least one-half minute before totality and continued to totality; then again from close of totality to at least one-half minute after. Bands approximately parallel and consisted of alternate bands of light and shade. Not sharply defined and shadow part of variable width. Bands seen nearest beginning and ending of totality best defined, the definition decreasing in quality in each direction from totality. Motion one metre, more or less, per second in direction perpendicular to bands. Azimuth of wave-crests, before totality, S. 45° W.; after totality, S. 48° W.

Reviewing the observations, Dr. Campbell concludes that the shadow phenomena cannot be produced by conditions exist-

ing on the moon. The wave-length of the shadow system was approximately 10 inches and the motion comparatively slow, namely, between one metre and three metres per second, and all the facts seem to indicate that the source of the disturbance lies in the earth's atmosphere. He continues: "The phenomenon may possibly proceed from the temperature gradient in the air masses immediately in front of and behind the position of the shadow cone in our atmosphere. The rapid cutting-off of the sun's rays before totality and the reverse process following totality, it is conceivable, may produce temperature or density gradients in the atmosphere favorable to effects upon the solar rays analogous to diffraction."

As stated elsewhere in this issue, the shadow bands were clearly seen at Matheson, Colo., and the observations made there agree with those recorded above. The shelter in which the present writer's instrument was placed was only half roofed over and the bands could be seen as they appeared within the shelter as well as through cracks in the walls. Dr. Campbell suggests diffraction, but the similarity of these bands to the wavy appearance produced when light passes along the surface of a heated body at once occurred to the writer. This, of course, is a refraction effect. Whether they be due to diffraction or refraction, it seems reasonable to expect that the bands should be parallel to the common tangent to the limbs of the sun and the moon at second and third contacts, or perhaps more precisely, in that tangent plane of the shadow cone which passes through the place of observation at these two moments. Can the refraction waves be due to passage of the radiation through the successive layers of the earth's atmosphere? If such is the case the bands should be less prominent with the sun near the zenith. Observations made at different distances from the central line would throw light upon the azimuth of the bands. At the present moment no literature on the subject is at hand, but the subject is worthy of further consideration.

NOVA AQUILÆ, NO. 3

Observations of the nova have occupied much of the attention of the astronomers during the summer, and several papers dealing with the star were presented at the recent meeting of the American Astronomical Society, a report of which will appear in the October number. Among these papers were two from the Ottawa observatory. One was by Mr. R. M. Motherwell on the magnitudes of the nova, which I hope will appear in the JOURNAL, soon; the other was by Mr. W. E. Harper on the spectrum and the velocity of the nova. This embodied the results which appeared in the last number of the JOURNAL, together with an extension of the same. It is interesting to note that the velocity obtained by him, namely 19·9 km. per second of approach agrees almost exactly with that obtained at Victoria, 19·7 km., and given by Dr. Plaskett in the present issue.

C. A. C.

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